Quantifying variability due to incidents including en-route rerouting

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1 Introduction

In dynamic traffic assignment (DTA) problems, reliability is increasingly acknowledged as an important factor influencing the decisions of travellers (such as modal choice, departure time choice and route choice). Several studies have tried to estimate the contribution of reliability to the choice behaviour of travellers, and to determine how and to what extent it is to be considered in choice models in DTA (e.g. [1], [2], [3], [4], [5]). However, before variability itself and the respons of drivers can be adequatly modeled by DTA models, several problems have to be overcome (see also [6]):

- Despite various studies (e.g. [1]-[5]), an agreement on the valuation and measure of variability to be used in generalised cost funtions in choice models (determing route choice, departure time choice and – in multimodal models – modal choice) is still to be reached.

- State-of-the-art Dynamic Network Loading (DNL) models used in DTA to propagate traffic over networks are deterministic by nature. With these models, the variability of traffic states and travel times from day to day can only be quantified by performing a large number of Monte-Carlo simulations with varying input (such as demand, route choice and capacity). Due to high computation times, this approach is unfeasible with state-of-the-art dynamic models. Thus, efficient algorithms are to be developped to produce – most likely in an approximate way - probability distributions of traffic states and route travel times, rather than a one-shot deterministic prediction. Recently, some first steps have been taken towards the development of such stochastic DNL models ([7],[8],[9]).
- Introducing variability may necessitate a reformulation of the DTA framework. It is questionnable if feeding DNL models with a route choice that is fully determined prior to departure – even if this route accounts for the influence of variability – and iterating towards a dynamic user equilibrium, sufficiently represents reality. Drivers may respond to variability not by a priori choosing a reliable route, but by opting for the fastest – not necessarily reliable – route and rerouting in case of above average congestion. This strategy is aided by various information systems available to drivers pre- and en-route. How and to what extent different levels of choice need to be considered in DTA to capture the dynamic character of traffic - this may differ depending on the application - is an open issue for future research and debate [10].

2 Including en-route rerouting in the Marginal Incident Computation model

In [11], we introduced the Marginal Incident Computation (MIC) model, a highly efficient algorithm that approximately quantifies congestion spillback and the corresponding travel time increase due to incidents. The MIC model superimposes the effect of every incident onto the outcome of a single base DNL without incidents. This base simulation can be obtained from any existing DNL model. The output needed from the base DNL consist of the curves of the cumulative vehicle numbers, which consequently serves as input to the MIC model. The base cumulative curves of the links where the traffic flows are influenced are altered according to the additional constraint imposed by the incident. This is done according to Newell's simplified first-order kinematic wave theory [12]. Since only the additional congestion due to an incident is calculated, computational effort is limited to a fraction of all links and time intervals. Computation time can be reduced to less than 0.1% compared to a full, explicit simulation of each incident case (depending on the network size). Thus, the MIC model renders extensive Monte-Carlo sampling feasible, allowing fine sampling of incident duration, severity, and starting times. In [9], the usefulness of the MIC model in the context of a stochastic DNL is demonstrated. By accounting for incident induced variability, an onset of a (partial) answer to the second question formulated in Section 1 is provided.

A rather stringent assumption of the MIC model as presented in [11] was that drivers make the same journey in case of an incident as they do in the base simulation. In this paper, an approximate procedure is added to the MIC model to account for en-route rerouting. This procedure is based on the hybrid route choice modeling introduced in [13]. Herein, a route choice model defines pre-trip route choice for all drivers. However, during the DNL, the pre-trip computed route flow rates are updated at every network node. This allows drivers to re-evaluate the pre-trip route choice and possibly deviate to an alternative route. An additional term (weighted with one single parameter ω) is introduced into the cost functions of the logit route choice model to express drivers' reluctance to move away from their initial route.

En-route rerouting is incorporated into the MIC model in the following way. At every node that the queue spilling back from the incident reaches, a *k*-shortest path logit route choice model is run. This route choice is performed between each initial route that passes through this node into the link from which congestion spills back and the *k* alternatives from this node towards the destination of the initial route. The cost function used in the logit route choice model contains the instantaneous route travel times and, for the alternative routes, the additional term to account for drivers' reluctance to reroute (as in [13]). In reality, drivers will have incomplete – and possibly incorrect - information about current and future traffic conditions and travel times. In any case, this route choice is not an equilibrium since this cannot be reached under unexpected traffic conditions. Here, drivers are assumed to base their en-route route choice on instantaneous travel times, which is probably more realistic than using experienced travel times, since these are unknown to drivers. At each node, the en-route route choice model determines how many people reroute and thus how the turning fractions (determining the proportion of traffic in each downstream direction) change. Due to rerouting, a higher proportion of drivers is directed towards non-congested downstream links and thus the outflow of each incoming link of the node will increase. As a result, the incident congestion will spill back slower and reach less far.

References

[1] N. De Palma and N. Picard, "Route choice decision under travel time uncertainty", *Transportation Research Part A* 39, 295-324 (2005).

[2] W. Jackson and J. Jucker, "An empirical study of travel time variability and travel choice behavior", *Transportation Science* 16(4), 460-475 (1981).

[3] T.C. Lam and K.A. Small, "The value of time and reliability: measurement from a value pricing experiment", *Transportation Research Part E* 37, 231-251 (2001).

[4] H.X. Liu, W. Recker and A. Chen, “Uncovering the contribution of travel time reliability to dynamic route choice using real-time loop data”, *Transportation Research Part A* 38, 435-453 (2004).

[5] R.B. Noland, K.A. Small, P.M. Koskenoja and X. Chu, “Simulating travel reliability”, *Regional Science and Urban Economics* 28(5), 535-564 (1998).

[6] R Batley, J. Bates and S. Hess, “Multimodal travel time variability”, *ITS Leeds* (2008).

[7] A. Sumalee, R. Zhong, W.Y. Szeto and T. Pan, “Stochastic Cell Transmission Model: Traffic State Modeling Under Uncertainties”, *Presented at the 88th Annual Meeting of the Transportation Research Board*, January 11-15, 2009.

[8] M. Ng and S.T. Waller, “Dynamic Route Choice Modelling in Face of Uncertain Capacities”, *Presented at the 88th Annual Meeting of the Transportation Research Board*, January 11-15, 2009.

[9] R. Corthout, C.M.J. Tampère and L.H. Immers, “Stochastic Dynamic Network Loading for Travel Time Variability due to Incidents”, To appear in *New Developments in Transport Planning: Advances in Dynamic Traffic Assignment (Proceedings of DTA2008, Leuven),* Edward Elgar, Cheltenham, UK - Northampton, MA, USA (2008).

[10] F. Viti and C.M.J. Tampère, “Dynamic Traffic Assignment: Recent Advances and New Theories towards Real-time Applications and Realistic Travel Behaviour”, To appear in *New Developments in Transport Planning: Advances in Dynamic Traffic Assignment (Proceedings of DTA2008, Leuven),* Edward Elgar, Cheltenham, UK - Northampton, MA, USA (2008).

[11] R. Corthout, C.M.J. Tampère and L.H. Immers, “Marginal Incident Computation, An Efficient Algorithm to Determine Congestion Spillback due to Incidents”, *Transportation Research Record* 2099, 22-29 (2009).

[12] G.F. Newell, “A simplifief theory of kinematic waves in highway traffic, Part I: General Theory, Part II: Queuing at freeway bottlenecks, Part III: Multi-destination flows”, *Transportation Research B* 27, 281-313 (1993).

[13] A.J. Pel, M.C.J. Bliemer and S.P. Hoogendoorn, “Hybrid route choice modeling in dynamic traffic assignment”, *Transportation Research Record* 2091, 100-107 (2009).